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Ten years of the INTEGRAL Burst Alert System (IBAS)

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The INTEGRAL Burst Alert System (IBAS) has been developed to detect and locate in real time the gamma-ray bursts (GRBs) serendipitously observed by INTEGRAL. The IBAS software runs automatically at the INTEGRAL Science Data Centre (ISDC), where the satellite data are received with a delay of only a few seconds. The sky coordinates of the GRBs occurring in the field of view of the IBIS instrument are distributed via Internet in real time. The localizations have a typical uncertainty radius of 2 arcmin (90% c.l.) and in most cases are available within a few tens of seconds after the beginning of the GRB. In ten years of operations IBAS has localized about 90 GRBs, most of which in near real time, and distributed alerts also for other kinds of astrophysical transient events, such as type I bursts from low mass X-ray binaries, flares and bursts from magnetars, and outbursts of Galactic transients. IBAS also provides the light curves for the GRBs detected with the anti-coincidence shield of the SPI instrument. Here I summarize the main properties of the GRBs detected in the field of view of IBIS during the first ten years of the INTEGRAL mission.

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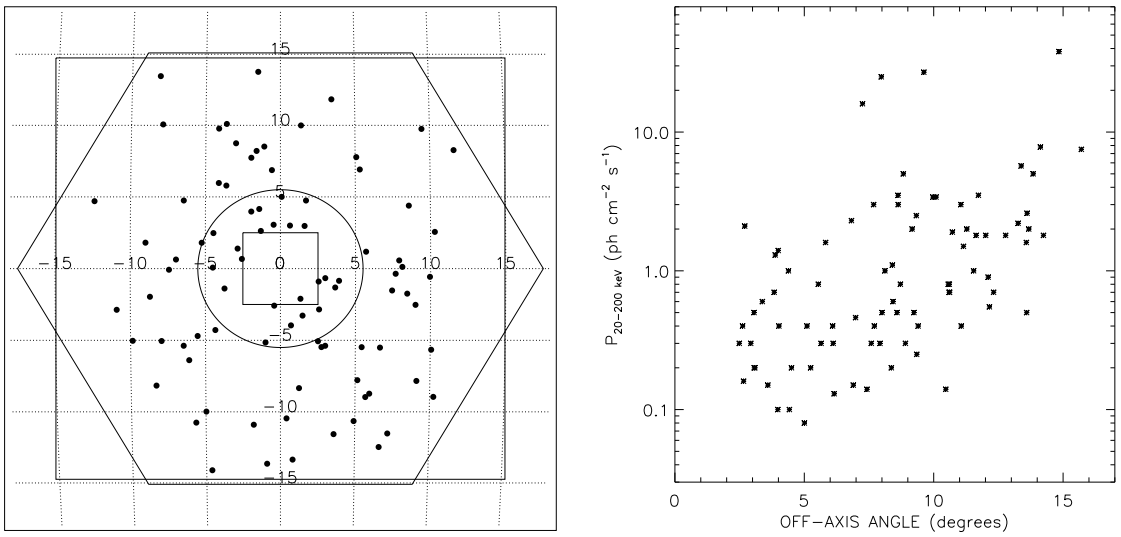

Figure 1: *Left panel:* Positions of the GRBs in the fields of view of IBIS [3] (large square), SPI [4] (hexagon), JEM-X [5] (circle) and OMC [6] (small square). *Right panel:* GRB peak flux (20-200 keV) as a function of the off-axis angle.

1. Introduction

The IBAS software [1] runs in real time at the INTEGRAL Science Data Centre [2], where the INTEGRAL telemetry is continuously received from the Mission Operation Center on a 128 kbs dedicated line. IBAS is based on a flexible multi-thread architecture that allows different triggering algorithms to operate in parallel on the IBIS/ISGRI data in order to detect, localize and validate GRBs (and other transients) in the field of view of IBIS. Alerts with the positions of GRBs detected with high significance are generated and distributed automatically. Quick-look interactive analysis to confirm the triggers and derive refined GRB parameters is carried out at IASF-Milano and CEA-Saclay. Lower significance triggers are also checked and may in some case lead to manually generated alerts. Thanks to IBAS, INTEGRAL has been the first mission to distribute in real time the positions of GRBs with arcminute accuracy.

Since the beginning of 2011, alerts for triggers of intermediate significance are also distributed automatically to the IBAS users who request them, e.g. for use with robotic telescopes. Although most of these triggers cannot be confirmed as GRBs, based only on INTEGRAL data, they might be validated by the presence of optical and/or X-ray counterparts. Note that two of the four short GRBs detected by INTEGRAL (GRB 100703A and 110112B) produced triggers of intermediate significance, that were subsequently confirmed by an interactive analysis.

In the following I summarize some properties of all the GRBs detected up to now (2012 November) in the field of view of the IBIS instrument. More details on the global properties of a smaller sample ($\sim$2002-2007) can be found in [7] and [8]. For updated information on IBAS and on GRBs detected by INTEGRAL see also *http://ibas.iasf-milano.inaf.it/*.

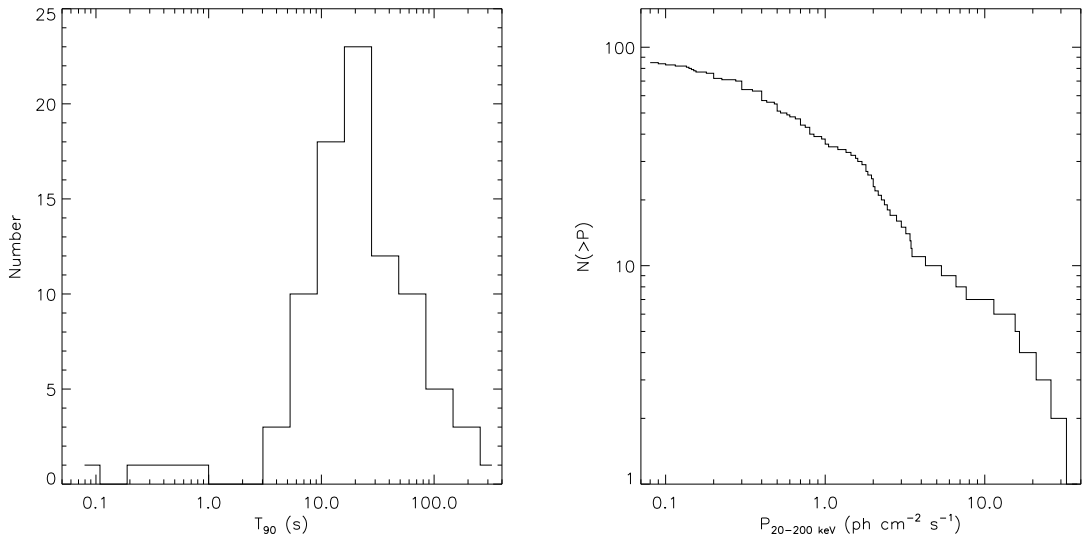

Figure 2: *Left panel:* Distribution of the GRB durations. *Right panel:* LogN-LogP integral distribution of the long GRBs detected with IBIS.

2. GRBs in the IBIS field of view

During the first ten years of the INTEGRAL mission, 89 GRBs have been detected in the field of view of IBIS. Some of their properties are listed in Table 1. The Table gives the approximate start time, T_{90} duration, and peak flux in the 20-200 keV energy range for each burst. The peak fluxes refer to an integration time of 1 s, except for the four short bursts (as indicated in the *Notes* column). The detection of a radio (R), optical (O) or X-ray (X) afterglow is indicated in the *Cpts* column (lower case letters refer to non-confirmed counterparts). The *IBAS* column indicates whether the GRB position was automatically distributed in real time (RT) or with a delay (D) after interactive verification. Two events initially reported as GRBs are not included in the table: they are GRB 071017, which is positionally consistent with the X-ray source AX J1818.8–1559 and is most likely a Galactic soft gamma-ray repeater [9], and GRB 120118A, probably a spurious trigger caused by the X-ray binary GX 301–4.

Figure 1 shows the positions of the GRBs in the field of view of the INTEGRAL instruments (left panel) and their peak fluxes as a function of the off-axis angle (right panel). The triggering sensitivity is practically constant within the IBIS fully coded field of view (the central $\sim 9^\circ \times 9^\circ$), while it decreases at larger off-axis angles. Note that the size of the error region depends only on the statistical significance of the source detection, therefore accurate localizations can be obtained also for the GRBs detected at very large off-axis angles. Only one GRB occurred inside the small field of view of the OMC (Optical Monitoring Camera) instrument ($\sim 5^\circ \times 5^\circ$), but unfortunately it was located very close to one of the brightest stars in the sky, which caused saturation of the OMC image at the burst position.

The distribution of GRB durations is shown in the left panel of Fig.2. IBIS detected four short bursts: GRB 070707, GRB 081226B, GRB 100703A, and GRB 110112B.

The right panel of Fig.2 shows the integral distribution of the peak fluxes of the 85 long GRBs.

A maximum likelihood estimate [10], excluding the region below 0.4 photons cm^{-2} s^{-2} which is affected by incompleteness, indicates that the distribution can be described by a power-law N($>$P) $\propto P^{-\alpha}$ with α=0.6$\pm$0.1.

3. Acknowledgments

I would like to thank J.Borkowski, D. Götz and all the other scientists and software engineers who contributed to the development of IBAS, as well as all the operational staff at the ISDC, coordinated by C.Ferrigno, for their continuous support.

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GRB	Time UT	T_{90} s	Peak Flux ph cm^{-2} s^{-1}	Ctpts	IBAS	Notes
021125	17:58:25	24	16.	-	D	During IBIS Performance/Verification Phase
021219	07:33:54	5	3.4	-	D	
030131	07:38:49	124	1.9	O	D	Detected during a satellite slew
030227	08:42:02	15	0.8	OX	D	Alerts disabled during Crab observ.
030320	10:11:49	48	7.5	-	D	Below threshold for automatic alert delivery.
030501	03:10:02	25	2.2	-	RT	
030529	19:53:18	16	0.14	-	D	during solar flare; detected off-line
031203	22:01:27	19	1.5	ROX	RT	z=0.105, SN 2003lw
040106	17:55:10	48	0.7	OX	RT	
040223	13:24:51	198	0.3	X	RT	
040323	13:02:58	14	1.8	o	RT	
040403	05:08:03	15	0.4	-	RT	
040422	06:57:59	4	2.5	O	RT	
040624	08:21:35	27	0.55	-	D	Below threshold for automatic alert delivery
040730	02:12:06	42	0.3	-	RT	
040812	06:01:52	8	0.6	oX	RT	
040827	11:50:50	32	0.7	OX	D	Below threshold for automatic alert delivery
040903	18:17:58	7	0.3	-	RT	
041015	11:11:33	30	0.25	-	D	Below threshold for automatic alert delivery
041218	15:45:44	38	2.6	O	RT	
041219A	01:42:13	239	$>$15	RO	RT	T_{90}=460 including precursor
050129	20:03:05	30	0.3	-	D	Below threshold for automatic alert delivery
050223	03:09:00	30	0.5	X	D	z=0.584? - one IBIS module off
050502	02:14:00	$>$11	1.4	O	RT	z = 3.793? - Started during satellite slew
050504	08:00:50	44	0.4	X	RT	
050520	00:05:57	52	1.0	X	RT	
050522	06:00:21	11	0.2	x	RT	
050525A	00:02:53	9	38.	OX	D	z=0.6; detected off-line (very off-axis)
050626	03:46:07	56	0.3	-	RT	In OMC field of view, at 2′ from α Crucis
050714	00:05:53	34	0.4	oX	RT	
050918	15:36:38	280	1.8	x	D	Below threshold for automatic alert delivery.
050922	13:43:20	10	0.1	-	D	Below threshold for automatic alert delivery.
051105B	11:05:41	14	0.4	-	RT	
051211B	22:06:07	47	0.8	OX	RT	
060114	12:39:31	80	0.16	-	RT	
060130	04:56:29	19	0.2	-	D	Below threshold for automatic alert delivery.
060204A	13:19:39	52	0.2	-	RT	
060428C	02:30:35	10	3.5	-	-	Detected off-line - IBAS temporarily not running
060901	18:43:55	16	7.8	oX	RT	
060912B	17:32:11	140	0.15	-	RT	
060930	09:04:12	9	0.6	-	RT	
061025	18:35:53	11	1.1	OX	RT	
061122	07:56:50	12	$>$17	OX	RT	

Table 1: GRBs in the IBIS field of view.

GRB	Time UT	T_{90} s	PF ph cm^{-2} s^{-1}	Ctpts	IBAS	Notes
070309	10:00:39	22	0.3	X	RT	
070311	01:52:34	32	0.9	OX	RT	
070615	02:20:37	15	0.5	X	RT	
070707	16:08:38	0.7	1.8	OX	RT	Short (peak flux on 0.7 s)
070925	15:52:32	19	>2	X	RT	
071003	07:40:55	148	5.7	OX	D	One IBIS module off
071109	20:35:55	30	0.46	r	RT	
080120	17:28:28	15	3.	OX	RT	
080414	22:33:30	8	1.	-	RT	
080603A	11:18:15	150	0.5	OX	RT	z=1.688
080613A	09:35:21	30	1.3	OX	RT	
080723B	13:22:15	95	25.	X	RT	
080922	11:03:36	60	1.	-	RT	
081003A	13:46:00	15	0.3	X	RT	
081003B	20:48:08	20	3.	-	RT	
081016	06:51:31	30	>2.4	X	RT	
081204	16:44:55	12	0.7	X	RT	
081226B	12:13:11	0.5	3.	-	RT	Short (peak flux on 0.2 s)
090107B	16:20:36	15	2.3	X	RT	
090625B	13:26:20	8	2.	X	RT	
090702	10:40:37	6	0.15	X	RT	
090704	05:47:43	70	2.	-	D	Below threshold for automatic alert delivery.
090814B	01:21:08	42	0.4	X	RT	
090817	00:51:23	30	2.1	X	RT	T_{90} does not include bump at t_0+200 s
091015	23:00:17	100	0.08	-	D	Below threshold for automatic alert delivery.
091111	15:21:59	100	0.1	-	D	Below threshold for automatic alert delivery.
091202	23:10:04	25	0.13	oX	RT	
091230	06:27:00	70	0.2	OX	RT	
100103A	17:42:30	30	3.5	X	RT	
100331A	00:30:22	9	0.5	-	RT	
100518A	11:33:37	25	0.5	OX	RT	z=4 (photometric)
100703A	17:43:37	0.06	2	-	D	Short (peak flux on 0.01 s), Below threshold for automatic alert delivery
100713A	14:35:50	20	0.4	X	RT	
100909A	09:04:00	60	0.14	OX	D	Below threshold for automatic alert delivery
100915B	05:49:38	4	0.8	-	RT	
101112A	22:10:20	6	1.6	rOX	RT	
110112B	22:24:55	0.3	5.	-	D	Short (peak flux on 0.1 s), Below threshold for automatic alert delivery
110206A	18:08:10	15	1.6	OX	RT	
110708A	04:43:30	50	0.8	ox	RT	
110903A	02:38:30	430	3.4	X	RT	
120202A	21:40:00	70	0.2	-	RT	
120419A	12:56:40	15	0.4	x	RT	
120512A	02:41:40	20	5.	-	D	Below threshold for automatic alert delivery
120711A	02:44:38	135	27.	OX	RT	
120821A	13:23:35	12	0.7	x	RT	
121102A	02:27:02	25	1.8	X	RT	Also Swift/BAT

Table 2: Continuation of Table 1.